

Titre: Framework proposal for ecodesign integration on product portfolio management
Title:

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Date: 2018

Type: Article de revue / Article

Référence: Paula Pinheiro, M. A., Jugend, D., Demattê Filho, L. C., & Armellini, F. (2018). Framework proposal for ecodesign integration on product portfolio management. Journal of Cleaner Production, 185, 176-186.
Citation: <https://doi.org/10.1016/j.jclepro.2018.03.005>

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URL de PolyPublie: <https://publications.polymtl.ca/3057/>
PolyPublie URL:

Version: Version finale avant publication / Accepted version
Révisé par les pairs / Refereed

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Document publié chez l'éditeur officiel

Document issued by the official publisher

Titre de la revue: Journal of Cleaner Production (vol. 185)
Journal Title:

Maison d'édition: Elsevier
Publisher:

URL officiel: <https://doi.org/10.1016/j.jclepro.2018.03.005>
Official URL:

Mention légale: ©2018. This is the author's version of an article that appeared in Journal of Cleaner Production (vol. 185) . The final published version is available at
Legal notice: <https://doi.org/10.1016/j.jclepro.2018.03.005>

Framework proposal for ecodesign integration on product portfolio management

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Abstract

Although many studies on product portfolio management (PPM) and ecodesign exist, there are few investigations that analyze these areas in an integrated way. They are normally conceptually separated, with very few theoretical and empirical interactions evident in the literature. This article proposes a theoretical framework that integrates ecodesign practices, methods, and tools with portfolio management during the product planning stage. For the development of this framework, a systematic analysis and literature review of both PPM and ecodesign were conducted. The framework subsequently developed was evaluated through a pilot test within two companies that develop products derived from Brazilian biodiversity. In terms of results, it presents a set of practices that are associated with the following dimensions: Guides, Methods, and Tools; Organization; and Strategy. After presenting the evaluation of the framework by the companies, practices are proposed which can be useful for the integration of ecodesign into PPM, such as adoption of the Project Management Office (PMO) and the use of social media.

Keywords: ecodesign, sustainable design, product portfolio, development of environmentally sustainable products, green product development, green innovation.

1. Introduction

Patterns of production and consumption have undergone significant changes over recent decades (Smith and Offodile, 2016), not least with factors such as global climate change and biodiversity loss having become increasingly relevant, and the number of consumers concerned about these issues growing (Dangelico and Vocalelli, 2017; Ji et al., 2015). As a consequence, the development of practices and products that seek to minimize impacts on the environment has become increasingly prominent (Rossi et al., 2016).

Due to the importance of sustainable development, then, the consideration of environmental criteria from the stage of product portfolio management (PPM) may have a positive impact on the development of environmentally sustainable products. This is particularly the case because late changes in new product development (NPD) projects can increase total costs and generate a greater impact on the environment (Boks, 2006; Jugend et al., 2017). Presenting a similar perspective, Cluzel et al. (2016) proposed a model for the generation and selection of eco-innovation project portfolios, suggesting the adoption of

ecodesign at all stages, from the generation of ideas to the selection of projects to be developed.

PPM presents an opportunity to improve environmental impact in the NPD process, since it is at this moment that more possibilities for the choice of product characteristics exist, including the use of materials that consume less energy, products that use raw materials from fair trade, and so on (Bocken et al., 2014; Jugend et al., 2017; Ölundh and Titzén, 2004). In addition, PPM is relevant in terms of companies coherently deciding on their marketing strategies and, for instance, how green their product portfolio should be (Dangelico and Vocalelli, 2017). This is also a promising avenue for locating sustainability as a strategic axis for project selection and the prioritization of technological projects, which is a current challenge for the emerging fields of green innovation (Schiederig et al., 2016) and the circular economy (Sauvé et al., 2016).

At the same time, the literature has demonstrated the possibility of integrating ecodesign in industry, in order to guide and encourage product designers to apply principles of environmentally sustainable development (Brones et al., 2014; Eppinger, 2011; Pigosso et al., 2013; Sihvonen and Patanen, 2016). However, there are few studies that analyze these relationships more deeply. Therefore, some studies suggest the need to broaden research on ecodesign integration in the stages of product project selection (Brones and Carvalho, 2015; Brones et al., 2014; Carvalho and Rabechini Jr., 2017; Sihvonen and Partanen, 2016). For example, Carvalho and Rabechini Jr. (2017) indicate that the bridge between project management and sustainability is still being built, and that, in order to build this bridge, processes, tools, and techniques are needed. Studies such as Rossi et al. (2016) and Silvius et al. (2017) also suggest that there is a need to expand research that develops and proposes specific frameworks and guides that support managers in their decision-making activities in the selection of projects for environmentally sustainable products.

This study aims to contribute to this area by proposing a framework for the integration of ecodesign into PPM. In this context, we have formulated the following primary research question: How can product portfolio management be used for the effective introduction of ecodesign practices, methods, and tools?

Despite the apparent availability of studies suggesting the adoption of practices, methods, and tools for the application of ecodesign, other researchers have pointed out that its practical application is still incipient in companies (e.g., Dekoninck, et al., 2016; Rossi et al., 2016; Silvius et al., 2017). Some studies have proposed the adoption of sustainability in the initial stages of NPD process from different perspectives (e.g., Brook and Pagnanelli, 2014;

Chang et al., 2013; Koga and Aoyama, 2008). Koga and Aoyama (2008) developed a method to design the optimal modular structure considering the life cycle of product family. Ölundh and Ritzén (2004) and Chang et al. (2013) suggested the application of methods such as stage-gates, green quality function deployment, and design structure matrix during the early product development stages. Taking a different perspective, our study proposes a framework with the tripartite dimensions of Guides, Methods, and Tools; Organization; and Strategy for the integration of ecodesign into PPM.

Initially, this theoretical framework was developed from a literature review. After that, the framework was evaluated by two companies with differing levels of maturity in the application of ecodesign, and which develop products derived from Brazilian biodiversity. The concern for integrating ecodesign into PPM can be considered important, especially for firms developing products based on biodiversity, as they are companies involved in the development of products that directly impact species and ecosystems (Jabbour et al., 2018; Primmer et al., 2015). As such, the adoption of ecodesign can decrease the main causes of biodiversity loss, such as over-exploitation of natural resources, pollution, and soil contamination (Alvarado-Quesada et al., 2014).

The article is structured in five sections. Section 2 presents the theoretical concepts in PPM and ecodesign. Section 3 presents the research method used in this research. Section 4 proposes the theoretical framework and its subsequent evaluation by the companies. Section 5 discusses the results. Finally, Section 6 outlines our conclusions.

2. Literature Review

2.1 Product Portfolio Management

Since the 1960s the discussion on how to allocate resources in new product and R&D projects has been studied by works in the area of innovation (Bitmans and Sharif, 2008; Spieth and Lerch, 2014), NPD (Cooper et al., 1999; Kester et al., 2014), and project management (Archer and Ghasemzadeh, 1999; Killen, 2017). In general, PPM's role is to select, from a series of project options, those most in line with the firm's strategy (Kopmann et al., 2015), the prioritization, acceleration and discontinuity of the projects and also the optimal allocation of resources between them (Cooper et al., 1999).

It is also known that the good performance of a product portfolio is fundamentally aimed at achieving the following objectives: (i) strategic alignment: translate the company strategy into a set of products in order to consider the current and future product lines and

determine which will be responsible for the viability of the innovation strategy (Cooper et al., 1999; Jugend et al., 2016; McNally et al., 2009); (ii) balance: the degree of innovation of the product projects that compose the portfolio (e.g., incremental and radical) and low risk/return projects (Cooper et al., 1999; Kester et al., 2014); (iii) maximized portfolio value: optimize the relationship between resources used and expected returns with product projects (e.g., Cooper et al., 1999; Kester et al., 2011); and (iv) preparing for future: benefits brought about by the new projects in the medium and long term for the creation of new markets, improved technologies, and to build new skills and competences to react to external challenges (Kock et al., 2015).

However, it is known that due to resource limitations and because they are related to the fuzzy front end of innovation (Browning and Yassine, 2016), and occur in the planning phase of new product projects, decisions that relate to PPM can be difficult and complex (Cooper et al., 1999; Kester et al., 2011). Many companies fail at the strategic level because they generally focus on individual product projects and do not integrate them into other projects and strategic planning (e.g., Cooper et al. 1999; Jonas, 2010). Archer and Ghasenzadeh (1999) emphasize that if, on the one hand, companies have many projects, on the other hand, there is a limitation of time, financial and human resources for their adequate development, which hinders the optimal choice of projects.

Given the strategic role of PPM and the need to support managers to better manage this process, there are different practices suggested in the literature that are recommended for achieving adequate performance in the product portfolio. The applications of these practices can be useful for evaluating strategic, market, technological and risk factors, as well as the economic return of the product portfolio (Brownin and Yassine, 2016; Verbano and Nosella, 2010). Among these practices, we can exemplify the inter-functional integration (Perks, 2007) through the adoption of multifunctional teams (Kester et al., 2011) and project teams (Lerch and Spieth, 2013); the use of formal management methods, such as financial (Jugend et al., 2016) and scoring (Bitmans and Sharif, 2008); and the association between the product portfolio and strategic planning (Brook and Pagnanelli, 2014).

In order to provide PPM support, Jugend and Silva (2014) proposed a framework that is based on the three dimensions of Methods, Organization and Strategy. This is the only framework that we find in the literature to support PPM. In this framework, mechanisms such as financial, scoring and ranking, for example, are part of the dimension of Methods. Elements such as profile and leadership style, the need for functional integration and organizational structures for PPM are addressed by the organizational dimension. The

relationship between the PPM and the strategic planning processes and their respective revisions is part of the Strategy dimension.

2.2 Ecodesign

Ecodesign aims to design products where the minimizing of their environmental impact throughout their life cycle is considered (Karlsson and Luttrupp, 2006; Jabbour et al., 2018). In an ecodesign-based product, design, quality and customer satisfaction requirements must be integrated with environmental requirements, so that solutions are considering their impact during all stages of the product life cycle, from raw material extraction through to manufacturing, packaging, use, recycling and reuse (Bovea and Perez-Belis, 2012; Luiz et al., 2016).

However, it is known that many companies face trade-offs among the development of environmentally sustainable products including in areas such as their production costs, final prices, functions that the product can perform and its environmental impact (Luchs et al., 2012). When adopting an ecodesign, the objective is to find a balance between requirements and environmental impacts and these functionalities and good performance in NPD (Luttrupp and Lagerstedt, 2006; Pigosso et al., 2013). Thus, ecodesign aims essentially to contribute to the development of eco-efficient products, implying the initial considerations of environmental requirements in the first phases of the NPD without negatively impacting the traditional characteristics of the products, such as design, sales price, reliability, time to market, among others (Pigosso et al., 2010).

Ecodesign and concern for green product development can also help organizations achieve benefits: (i) economics, such as optimization of raw material consumption and energy use, reduction of water consumption, improvement of waste management, reduction of production costs (Bocken et al., 2014; Fiksel, 2012); (ii) market, achieving higher customer satisfaction, gaining new customers, acquiring a better reputation and higher sales (Dangelico, 2017); (iii) innovation, related to the application of eco-innovation and new technologies of product and process (Bocken et al., 2011; Dangelico and Vocalelli, 2017); and, (iv) compliance with legal requirements (Dalhammar, 2010; Vercalsteren, 2001). Therefore, there are a number of publications that recommend the adoption of ecodesign in order to improve the environmental performance of products throughout their life cycle (Brones and Carvalho, 2015; Byggeth and Hochschorner, 2006; Dangelico, 2017; Luiz et al., 2016).

1 In order to guide companies in applying ecodesign, some studies propose their
2 operationalization through the use of specific practices, methods and tools (e.g., Bocken et al.
3 2014; Bovea and Perez-Belis, 2012; Byggeth and Hochschorner; 2006; Luttrupp and
4 Lagerstedt, 2006; Moreira et al., 2014; Rossi et al., 2016), and they note that the more
5 anticipated these adoptions are in the NPD stage, the better environmental gains and impacts
6 that can be achieved in the development of the new product (Collado-Ruiz and Ostad-Ahmad-
7 Ghorabi, 2013; Luiz et al., 2016).

8 Le Pochat et al. (2007) have classified tools of ecodesign into two groups: one with a
9 qualitative approach, e.g. guidelines, strategies, principles and lists of prohibited or non-
10 recommended materials; and one with a quantitative or semi-quantitative approach, having as
11 examples the MET (materials, energy, and toxicity) matrix, and product life cycle assessment.
12 Other methods are also widely mentioned in the ecodesign literature, such as: environmental-
13 quality function deployment (EQFD), environmental failure mode effects analysis (E-FMEA),
14 and ecodesign checklist (Bovea and Pérez-Beliz, 2012; Byggeth and Hochschorner, 2006;
15 Cluzel et al., 2016; Knight and Jenkins, 2009).

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3. Research Method

66 This research takes a qualitative approach in order to develop a new understanding of
67 the phenomenon of integrating ecodesign with PPM. The development of this research
68 comprised two complementary phases. The first is a theoretical study aimed at identifying and
69 analyzing relevant studies regarding the integration of the themes “PPM” and “ecodesign”,
70 which then served as basis for the elaboration of a theoretical framework. The second phase
71 involved workshops for the pilot test evaluation of the framework with teams of product
72 developers from two companies specializing in biodiversity. These companies have different
73 levels of maturity in terms of implementing environmental issues into the NPD. The
74 following discussion details these phases.

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1001 As noted above, the framework presented in this study was developed from the
1002 literature review. To ground the theoretical research, the following terms were considered:
1003 “product development process”, “product portfolio”, “new product development” and “NPD”,
1004 which were applied in conjunction with: “ecodesign”, “eco-design”, “green product”, “eco-
1005 innovation”, “design for environment” and “DFE. These terms are often used in areas of NPD

and PPM (e.g., Cooper et al., 1999; Kester et al., 2014; Jugend et al., 2016), as well as in ecodesign and green product development (e.g., Fiksel, 2012; Luiz et al., 2016; Rossi et al., 2016). The Scopus database was consulted because it is the largest database in the fields of science, technology, medicine, social science, arts and humanities (Fahimnia et al., 2015).

The searches were carried out considering all publications with the key terms relating to the items Title-Abs-Key of Scopus. This resulted in 214 documents, of which 104 were conference papers, 97 articles in journals, five articles in press, four book chapters, and one book. The selection made for inclusion in this study consisted only of articles and articles in press that were published in journals, because such documents pass through stricter criteria of evaluation before publication. The elimination of duplicates and other types of documents (books, book chapters, and conference articles) resulted in 54 publications, which were then read. In addition, we added 21 new articles that dealt directly with the two themes (ecodesign and PPM), that were not initially found by the selective key word searches or which were published at a later date than when the original search was carried out (e.g., Rossi et al., 2016; Silvius et al., 2017).

After reading these publications, we interpreted ecodesign practices, methods, and tools that could be applied to PPM. For example, works such as Gouvinhas et al. (2016), Brones and Carvalho (2015), and Prendeville et al. (2014), which dealt with ecodesign, NPD, and project management, helped us to develop the proposed framework. Relevant studies in terms of citations (e.g. Byggeth and Hochschorner, 2006; Knight and Jenkins, 2009), and which dealt with these themes, were also useful for the development of the framework

The development of the framework was based on the proposal of Jugend and Silva (2014), because this is the only framework found in the literature to support the product portfolio and it has already influenced other works involved with NPD and PPM (e.g., Carbonell et al., 2016; Echeveste, et al., 2017; Nyström and Wellander, 2016). However, unlike the objectives of this research, Jugend and Silva's (2014) proposal deals only with PPM, not with integrating issues of environmental sustainability and the development of environmentally sustainable products.

The content analyzed in the literature review of ecodesign allowed for the relationship of most of the dimensions and practices already proposed by Jugend and Silva (2014), but some adjustments in the specific dimensions of the framework and insertion of content in ecodesign were made. For example, because similar content has not been applied to financial methods in ecodesign practices and methods (which is different from traditional PPM), these methods were not considered in the framework proposed in this article.

1 Some practices that were identified as relevant to ecodesign, which were not proposed
2 in the Jugend and Silva (2014) article, were also included in this study. This included
3 “sustainable development guides” and “top management support”. On the other hand,
4 “organizational structure” and “strategic planning” were not changed, since the ecodesign
5 literature is also based on integration that considers these activities, as already proposed by
6 the mentioned authors.
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10 *Phase 2: Pilot test assessment of the framework by biodiversity companies*

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12 In order to evaluate the theoretical framework proposed, we consulted practitioners
13 who work in firms that develop products derived from Brazilian biodiversity. To facilitate
14 this, a questionnaire was initially developed to identify and characterize the firms according to
15 their performance in the industry, as well as to identify their respective degree of maturity in
16 issues related to environmental practices. The questionnaire was constructed with
17 predominantly open questions and had the main intention of clarifying how environmental
18 management and ecodesign are adopted and integrated into the company’s product portfolio.
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27 The questionnaire was based mainly on the research of Brones et al. (2014), which
28 involved a case study and focused on identifying how environmental dimensions and
29 ecodesign can be integrated into the management practices of NPD projects. However, we
30 have adapted the issues to focus more on PPM. To evaluate this questionnaire, we first
31 applied it to a large company that develops environmental projects in civil construction and
32 which is certified by ISO 9001: 2015, ISO 14001:2004, and OHSAS 18001:2007. An
33 overview of the questionnaire can be found in the Appendix.
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40 For the examination of the theoretical framework, we looked for companies to
41 participate in evaluation workshops based on the following criteria: that they have new
42 product development activities, they frequently renew their portfolio, and they belong to the
43 biodiversity sector. An internet search was undertaken with the objective of finding
44 companies that fulfilled this profile. After this, telephone and e-mail contact were made with
45 five companies that met these requirements, with three of them answering the contact and
46 accepting the invitation to receive the questionnaire. Thus, the questionnaire was sent to these
47 three companies, two of which showed an interest in participating in the research, responding
48 to the material by e-mail and organizing an agenda of meetings in order to discuss answers to
49 the questionnaire and receive the researchers.
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We also aimed to evaluate the framework in companies with different degrees of maturity in environmental sustainability. For this, we used a classification suggested by Gouvinhas et al. (2016), with six stages of maturity (i.e., level 1 being completely immature and level 6 being fully mature). Initial meetings were held with companies A and B which allowed a better understanding of their practices of environmental sustainability, ecodesign, and PPM. In the next stage, we conducted workshops with these same firms in order to evaluate the framework.

- Characterization of companies

Due to issues of confidentiality, the companies will be referred to as company A and B in this article. Company A was founded in 1994 and has its administrative headquarters in the city of Sao Paulo, as well as operating a factory in the countryside of the state of Sao Paulo (Brazil). It currently has 113 employees and was a pioneer of the creation of antibiotic-free chicken in Brazil, which is free of both antibiotics and artificial growth promoters. In its mission, the company aims to integrate ecological and social values in the development and production of natural foods that are free of agrochemicals. In 2017, the company was acknowledged by the Brazilian Council for Organic and Sustainable Production as being the most recognized brand in organic products in Brazil.

This company's product portfolio consists of organic foods, antibiotic-free eggs, sustainable and organic beef, sustainable fish, an organic grocery line, and a line of sustainable products such as sausages, hamburgers, meatballs, and roast chicken. With the objective of developing eco-efficient packaging, the company has carried out tests with packaging made from manioc starch, which is totally biodegradable. Based on their responses to the first questionnaire, we realized that company A demonstrate concern with the entire supply chain cycle. These concerns guide the company, from choosing their portfolio and defining the concept of products from production to discontinuity, and involves applying knowledge from areas such as biology, food engineering and chemistry.

Company B operates in the timber industry and is in its second generation of family management. Founded in 1992, its production plants and its main office are located in the south-west of the state of Sao Paulo (Brazil) and it currently has 80 employees. The firm has a portfolio of products derived from reforestation eucalyptus wood, among which are toys for playgrounds (balances and seesaws, including ones that accommodate disabled children), equipment for gymnastics, showers and sinks with wood bases, and other such products. In addition, the company is currently responsible for an inclusive social project in Sao Paulo

1 state called “old people's square”, in which it has developed and manufactured several
2 ergonomic gymnastic devices for physical movement across more than 400 towns and cities
3 in this region of Brazil.
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5 Based on the responses received in the questionnaires and from information gathered
6 at the meetings that were held, companies A and B were classified according to the proposal
7 of Gouvinhas et al. (2016), with company A qualifying as a level 5 company (more mature)
8 and company B as level 2 (less mature). Company A demonstrated the characteristics present
9 at level 5 of maturity (Gouvinhas et al., 2016), because the company has demonstrated
10 activities including considering environmental issues in their business decisions, requiring
11 suppliers to meet environmental standards, and educating their clients to consider
12 environmental and social aspects during their consumption decisions. In addition, they have
13 formalized environmental processes (for products and processes) and already apply ecodesign
14 methods and tools.
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23 Due to the characteristics identified in company B, it qualifies as an immature
24 company (level 2 maturity) (Gouvinhas et al., 2016) because, while it is a firm that has started
25 to experiment with ecodesign. For Gouvinhas et al. (2016), at level two, companies are still
26 more concerned with the problems of profitability, cost reduction, and production efficiency,
27 rather than environmental aspects; however, they do already understand the importance for
28 new market opportunities that focus on aspects environmental and social issues and try to
29 implement projects in this field.
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38 - *Workshops for the evaluation of the framework* 39

40 For the second phase of this research, workshops were held in both companies to
41 evaluate and pilot test the framework developed. An initial meeting was scheduled to discuss
42 the practices of PPM and ecodesign in the firms, and later a second meeting was held in the
43 form of workshops in which the proposed theoretical framework was presented for evaluation
44 by managers. The industrial director and the research assistant participated in the meetings
45 and workshops at company A. In company B, the workshop was attended by the director, the
46 human resources manager, and the forestry engineer.
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53 In this phase, all the dimensions and theoretical groupings within the framework were
54 presented and discussed in detail. The objective of this activity was to obtain a better
55 understanding of the applicability of the proposed activities to the everyday reality of these
56 firms. During the workshops, we also asked for suggestions of other activities common to the
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practices of the companies that were not mapped in the literature, and that consequently were not present in the proposed framework.

4. Results

Initially this section presents the theoretical framework that was developed and proposed. Then, the results of the evaluations of this framework by the two companies selected are presented.

4.1 Framework for the integration of ecodesign on product portfolio management

Initially, it is important to highlight that although it is known that ecodesign has many management practices (Rossi et al., 2016), the development of this framework has considered only to those in which it was interpreted to have a possibility of practical application in the PPM, that is, in the planning stage of the NPD process. Figure 1 presents an overview of the proposed framework. Each one of the proposed dimensions is explained in the following paragraphs.

Figure 1 about here

- Dimensions of Guides, Methods and Tools

Consideration of a dimension for the adoption of guidelines and formal application of methods and tools is relevant to our subject of environmentally sustainable products, due to the need for companies to evaluate product projects and their environmental impact from formal and previously defined evaluations (Bovea and Perez-Belis, 2012). Diagrams, tools, checklists and guidelines are means for the adoption of environmental considerations into NPD (Rossi et al., 2016). However, as observed by Alblas et al. (2014) and Driessen et al. (2013), due to a lack of specific knowledge in ecodesign tools, some companies fail to consider the adoption of their practices in product project decisions, which may undermine environmental performance.

Because of this potential pitfall, the literature tends to defend the application of tools and methods that have a simple application in traditional portfolio management (Jugend and

Silva, 2014) as well as for the adoption of ecodesign (Byggeth and Hochschorner, 2006; Cluzel et al., 2016). The use of easy-to-apply tools and methods in the development of green products increases the possibility of companies overcoming limitations and barriers to their application, as well as optimizing the time and resources available for selecting and applying them (Ammenberg and Sundin, 2005). Table 1 presents the summary of the Guides, Methods and Tools dimension.

Table 1 about here

Among the suggested methods and tools, the ecodesign checklist method, scoring and ranking can be useful to PPM, since they are related to the life cycle of the products, evaluating criteria such as simplicity of the project execution; selection and decrease of the use of raw materials; the reduction of energy use; reduction of losses during use and at the end of use; reduction of the product's time of disassembly; and reuse and recycling and of the product, among others (Knight and Jenkins, 2009). The use of checklists and scoring mechanisms also allows managers to obtain a list with the classification of projects already ranked, which supports better environmental decision making in the projects yet to be effectively developed (Vezzoli and Sciama, 2006).

Diagrams and matrices are visual mechanisms that can promote the adoption of the life cycle approach and provide an illustrative way to evaluate the interactions between product design criteria, which may favor product portfolio decision making. Among these mechanisms are the matrices such as the MECO Matrix (Byggeth and Hochschorner, 2006) and the Matrix of Material, Energy and Toxicity (Knight and Jenkins, 2009) and the ecodesign strategy wheel (Cluzel et al., 2016). The filling of these matrices can be done by asking a question and choosing a value to sort the attribute analyzed, and the results can be used to compare new product projects with an existing reference product or to compare various environmental alternatives for product projects (Byggeth and Hochschorner, 2006).

Sustainable product development guides can be used to support companies with systems and procedures that facilitate decision making that consider the integration of environmental aspects with product development projects (Bocken et al., 2014). An example is ISO/TR 14062:2004, which involves environmental management and characterizes concepts and practices relating to the integration of environmental aspects into product

1 project, design and development. Another example is BS 8887-1: 2006, which establishes
2 general concepts, processes and requirements, a checklist with guidance for the delivery of
3 sustainable materials and components from design to fabrication, assembly, disassembly and
4 final processing of life (British Standards Institution, 2006).
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8 9 - *Dimension of Organization*

10 Given that organizational aspects should not be neglected for product portfolio
11 decision making, this dimension considers elements such as: integration with stakeholders;
12 multidisciplinary team; and environmental manager or specialist when planning the adoption
13 of ecodesign in PPM. Table 2 presents an overview of this dimension.
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18 19 20 **Table 2 about here**

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25 Considering the organizational design, integration with stakeholders is a relevant
26 element for the improvement of the decision-making process in the portfolio of
27 environmentally sustainable products since it also facilitates the identification of external
28 factors of environmental regulation and consumer demand for environmentally sustainable
29 product. In addition to facilitate the identification of external factors of environmental
30 regulation and consumer demand for environmentally sustainable products, it may also favor
31 the sharing of knowledge and information of perspectives and technical environmental aspects
32 of different stakeholders in the product project decision (Hoejmose et al., 2012; Marcelino-
33 Sádaba et al., 2015; Vezzoli et al., 2012). Juntunen et al. (2016) emphasize the importance of
34 integrating with stakeholders in the development of environmentally sustainable products,
35 because this involvement allows greater integration of knowledge from internal and external
36 sources to the company, aiming at what has the potential to generate more information on the
37 sustainability aspects of products.
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48 Multidisciplinary teams that have participation of members from several areas and
49 specialties of the firm can be considered relevant for the development of environmentally
50 sustainable products and can positively impact portfolio management (Hyung-Jin Park et al.,
51 2009). In these teams, the participation of environmental specialists tends to favor the
52 adoption of ecodesign methods and tools to choose products of environmentally sustainable
53 products in the composition of the portfolio (Bocken et al., 2014; Jabbour et al., 2015). Also,
54 the integration of ecodesign to the PPM tends to succeed more and to be carried out by
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employees who are committed to respecting the regenerative capacity of the nature and thus to develop mechanisms to review and to redesign traditional solutions in the development of products (Petala et al., 2010; Prendeville et al., 2014). Therefore, it is important that employees with this profile participate or lead the new product development teams.

In addition to the adoption of multifunctional teams, the literature has also indicated the relevance of the presence of leaders or managers who have the technical skills and management involved in the NPD process (Jugend and Silva, 2014; Prendeville et al., 2014). In this sense, researchers such as Borchardt (2010) and Johansson (2002) suggest that the presence of ecodesign experts contributes to the application of ecodesign in NPD decision making.

- Dimension of Strategy

Portfolio decisions tend to reflect strategic planning deliberations (Kopmann et al., 2015) and its periodic review activities (Jugend and Silva, 2014; Patterson, 2005). Similarly, decisions about the development of environmentally sustainable products and the adoption of ecodesign can also be aligned and their adoption intensified through the strategic activities of firms. This dimension is illustrated in Table 3.

Table 3 about here

In the face of strategic planning activities, some studies suggest the importance of linking the business strategy with the decision making in a portfolio of environmentally sustainable products (e.g., Byggeth and Hochschorner, 2006; Gouvinhas et al., 2016). Byggeth and Hochschorner (2006) identified that the application of ecodesign tools in strategic planning tends to positively influence firm performance. Gouvinhas et al. (2016) indicate the alignment between strategic planning and the effective adoption of ecodesign as an indication of maturity in environmental sustainability.

Another relevant factor for the consideration of environmental aspects in the development of environmentally sustainable products is the support of the top management (Petala et al., 2010), which can be a critical success factor for the adoption of ecodesign in moments of product portfolio decision making, whether in strategic planning (medium and long term) or portfolio review moments (short term).

1 Considering the market dynamics and the complexity of product development
2 decision-making in strategic planning, it is important to carry out portfolio review activities in
3 short periods of time to verify the alignment of projects with strategic planning (Patterson,
4 2005). For this operationalization, Goffin (2012) recommends integrating environmental
5 sustainability with the NPD process through the stage-gates model during product
6 development decisions. In addition to strategic approvals and decisions, portfolio reviews in
7 project development forums can also be used to verify that projects meet environmental
8 requirements, thus ecodesign methods and tools can also be incorporated into the stage-gates
9 model.

10 11 12 13 14 15 16 17 18 *4.2 Evaluation of the framework by companies*

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20 As detailed in the section of research method, with the objective of evaluating the
21 theoretical framework developed in firms, presentations and interviews were conducted in a
22 workshop format in Brazilian companies that develop products based on biodiversity and with
23 different levels of maturity in the adoption of ecodesign. Table 4 presents the results of the
24 Guides, Methods and Tools dimension.

25 26 27 28 29 30 31 32 33 **Table 4 about here**

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39 The application of environmental checklist methods, scoring and ranking for the
40 analysis of product projects, as well as the adoption of natural agriculture guides are practical
41 examples adopted by company A in PPM and are aligned with the proposed framework.
42 Company B, not adopting these formal methods and tools, suggested that their use could
43 effectively improve the management of choice of environmentally sustainable products and
44 was interested in adopting the proposed methods and tools in the framework

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49 It was added by company A that the activities related to product portfolio management
50 are managed by the new product development departament, using the Project Managment
51 Office (PMO) organizational structure, which establishes methods and supports the
52 management of new product projects and the environmental methods and tools associated
53 with this process.

1 Although the companies do not have guides recognized, they adopt other systems that
2 support decision making in environmentally sustainable products such as the philosophy of
3 natural agriculture (company A); and company B is in the process of being certified by the
4 Brazilian Association of Wood Preservers for the self-evaluation guide, which aims to
5 guarantee the quality and legality of the consumer of treated wood products. Table 5 presents
6 the results of the evaluation concerning the Organization dimension.
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18 Regarding organizational aspects, company A highlighted the use of information from
19 social medias as a mechanism that intensifies integration with its stakeholders. Because it is a
20 company that deals with biodiversity, the integration of users into its product projects through
21 the medias can be higher than with companies from other sectors due to the greater concern of
22 this type of consumer with the preservation of biodiversity. This fact may favor the
23 company's ability to understand stakeholder needs in product development decisions,
24 especially customers and representatives of society who are involved in biodiversity issues.
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31 The support of research institutions that are focused on agricultural research (in this
32 case, The Brazilian Agricultural Research Corporation - Embrapa) was also reported as a
33 relevant practice by company A for reinforcing the effective adoption of environmental
34 policies and guidelines for the decision-making processes relating to products, thereby
35 maintaining a sustainable point of view, since it inserts an external environmental specialist
36 into the process that acts in the research institute in PPM. Although the two companies
37 recognized the need for the participation of a multidisciplinary team in NPD projects with the
38 presence of an environmental specialist, it was highlighted by the director of company B that
39 smaller companies may not have a qualified professional completely dedicated to these works,
40 noting that it is important to consider also the hiring of an external consultant with specific
41 knowledge to participate in shorter periods of time in these teams. Table 6 presents the results
42 of the Strategy dimension.
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1 The two companies emphasized that integrating environmental sustainability and
2 applying ecodesign practices in PPM is only possible when top management offers support
3 from the strategic planning stages. The fact that top management members of the company A
4 participate in portfolio review meetings and support environmental sustainability right from
5 the stage of strategic planning is an element of organizational culture that is oriented toward
6 sustainability and can be considered a practice that strengthens the achievement of strategic
7 environmental objectives. This is due to the support for product development that is aligned
8 with environmentally sustainable design and development. In company B it was pointed out
9 that if the integration of ecodesign in the projects does not make sense to the top management,
10 there will be no prioritization in the selection of the projects of new products with the
11 environmental aspects. It was reported that while the application of the environmental
12 checklist, it is necessary to know if the requirements listed in this method are aligned with the
13 strategic objectives of the firm.

14 Company A has adopted stage-gates model and illustrated its use in their planning
15 product phase when in the technical evaluation of the gate, it was verified that it would be
16 necessary to use hormones in the new product. As the use of hormones in the product
17 portfolio is misaligned with the strategic positioning of the company, the project was
18 canceled. Respondents from company B emphasized that by positioning themselves in the
19 market for environmentally sustainable products, they are concerned with the environmental
20 impacts throughout the life cycle of their product, from the selection of raw material
21 (reforestation wood only) to the reuse techniques in the use of new products derived from
22 wood, for example, applying them on dormant landscaping and using them as organic matter.

23 Finally, comments made by company A's product team during the workshop suggest
24 that the framework developed in this paper and presented to the firms (Figure 1) has the
25 advantage of offering an organized visual approach to the adoption of ecodesign in the PPM
26 context.

27 5. Discussion

28 Regarding the existing literature, the framework proposed here adds a set of
29 dimensions in terms of management and groups of activities that contribute to the integration
30 of environmental aspects of portfolio management and green product development. This study
31 stands out from existing literature, not only for examining the possibilities of integrating
32 ecodesign tools and methods during the early stages of NPD, but also by merging that with

1 organizational and strategic approaches. Studies that suggest the adoption of environmental
2 issues in the early stages of NPD have focused mainly on methods and tools (e.g., Chang et
3 al., 2013; Koga and Aoyama, 2008; Ölundh and Ritzén, 2004). Even this framework has been
4 constructed based on ecodesign, there are synergies between this study and the proposal of
5 Brook and Pagnanelli (2014), which aimed to integrate sustainability in its three dimensions
6 (economic, social, and environmental) into breakthrough projects, platform projects, and
7 derivative projects.
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12 When analyzing the theoretical framework in relation to the reality of the companies,
13 it was observed that there was a greater adherence to the methods and tools found in the
14 literature in company A. This firm is more mature in terms of environmental management,
15 and effectively adopts practices such as gates for portfolio review and formal ecodesign tools,
16 such as an environmental checklist and scoring models (Bovea and Pérez-Beliz, 2012; Brones
17 and Carvalho, 2015; Byggeth and Hochschorner, 2006). Practices such as offering support
18 from top management (Dangelico, 2017; Petala et al., 2010) and the formation of
19 multifunctional teams (Bocken et al., 2014; Jabbour et al., 2015) for decision making in
20 relation to environmentally sustainable products are adopted by both companies, which
21 demonstrates that the organizational aspects proposed in the framework are reflected in
22 practice.
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33 Although the PMOs are consolidated structures in the areas of project management
34 and NPD (Bredillet et al., 2017; Unger et al., 2012), little is known about their application in
35 projects that involve environmental sustainability. The possibility of incorporating the PMO
36 as a structure that can support the adoption of ecodesign in PPM was a relevant contribution
37 used by company A for the proposed framework. This practice can integrate the ideas of
38 environmental sustainability as a school of thought in project management (Silvius, 2017).
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44 Policies that support R&D and open innovation through partnership with agencies,
45 institutions, and consultancies were also noted by both firms as being a common practice and
46 were not initially mapped in the specific literature that addresses ecodesign and PPM. In
47 company A, for example, there is a team working in partnership with the Brazilian
48 Agricultural Research Corporation (EMBRAPA) towards the development of indicators of
49 environmental and technical issues that assist with decision making in environmentally
50 sustainable products. In company B, it was highlighted that they use expert consultants or the
51 support of agencies such as the Brazilian Micro and Small Business Support Service
52 (SEBRAE). This confirms the proposal made by researchers such as Borchardt (2010) and
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Johansson (2002), that the presence of an environmental specialist, even if not in full-time, was pointed out as a possible contribution to the decision making and product portfolio.

With regard to open innovation and user involvement in the development of environmentally sustainable products, it was identified in the study of company A that the exchange of information through social networks is a relevant way of building relationship with the consumer and society, which was not included in the initially proposed framework. This activity seems to contribute positively to the process of monitoring the demands of the market, serving as one of the sources for the process of generating ideas for new product projects in the company. As this company is involved in biodiversity-based product development, there is a greater participation of consumers and other actors in society, who are traditionally more active and concerned with preserving biodiversity when compared to other economic sectors.

The observed synergy between environmental and social aspects is an important observation of the workshops. Both companies emphasized environmental and social practices as being inseparable, and demonstrated a strong relationship between these. This is supported by the proposal of Gouvinhas et al. (2016), which characterizes more mature companies as having the responsibility of trying to educate clients towards more conscious social behavior. For example, company A aims to integrate ecological and social values into the development and production of natural foods, and company B is currently responsible for an inclusive social project aimed at the elderly, as well as for developing products aimed at disabled children.

6. Conclusions

The framework proposed here aimed to meet an identified gap in the literature; namely, the need to consider environmental aspects from the earliest stages of NPD. By proposing a framework that was developed theoretically, and then evaluated by companies that develop products based on Brazilian biodiversity, the results presented here help to advance areas such as environmental sustainability, NPD, and project management. This framework systematizes a set of managerial practices that can facilitate the integration of ecodesign in PPM. Few investigations analyze these areas in an integrated manner, and the integration of ecodesign and project management has been called for in recent literature on environmental sustainability and project management.

1 With regards to managerial implications, we understand that the framework can guide
2 managers from diverse companies (not just those of biodiversity companies) to adopt or
3 intensify ecodesign and environmental concerns when making choices about new products, as
4 well as determining resource allocation activities among these projects. For example, the need
5 to train PMO managers in ecodesign activities was found in this study, which could facilitate
6 the integration of ecodesign into PPM.
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10 Despite the results obtained, this research also presents some limitations. Firstly,
11 certain ecodesign tools and methods found in the literature present application restrictions
12 during PPM but can be applied in other stages of the NPD process, for example, in the
13 conceptual and detailed design stages. Second, the evaluation of the framework focused its
14 research on only one food industry and one on the timber industry, which has a direct
15 relationship with biodiversity. It is possible that other industries, such as those belonging to
16 the electronic and automotive sectors could evaluate the conceptual framework differently,
17 which would generate new and alternative results compared to those outlined by this research.
18 As such, it is recognized that the empirical results of this study should be viewed with due
19 methodological caution, since its results cannot be generalized.
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29 Based on the results and limitations of this research, with the objective of identifying
30 new practices for the integration of environmental sustainability in PPM, we understand that
31 future research, also using a qualitative approach, could undertake complementary studies in
32 companies that work in different sectors and environments, including high-tech companies,
33 for example. Another important area for future studies would be to verify the possibility of
34 financial environmental evaluations, which were not identified in the literature in ecodesign,
35 or even highlighted in the framework's evaluation workshops. This theoretical framework can
36 be improved, not being a definitive effort. It can be continually improved, either by means of
37 new theoretical research or by empirical evaluations, which also suggests an important role
38 for future studies.
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49 *Acknowledgements: This research was funded by FAPESP – The Sao Paulo State*
50 *Research Foundation, Brazil (Grant # 15/00110-6).*
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42 Appendix 1. Overview of Questionnaire.

43 Part A

44 Company and Respondent Identification (Characteristics)

45 Part B

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50 1. In the new product development process, how does the company select the projects to be
51 developed?
- 52 2. Which stages comprise the process of new product development in the company?
- 53 3. Does the company have environmental or ecodesign concerns in the new product development
54 process? How are these identified?
- 55 4. Does the company consider environmental criteria when making decisions about which new
56 product projects it selects? How does this process work?
- 57 5. Does the company consider environmental criteria in decisions related to technologies chosen
58 or developed for new products? How are these identified?
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6. Do environmental issues interfere with the quality of the product project? How does this process work?
7. Do environmental issues interfere with the cost and price of the products? How does this process work?
8. Do environmental decisions interfere with the functional performance of the products?
9. Does the company develop products focusing on reducing resource consumption and waste generation during consumer use of the products? How does this work?
10. Does the company adopt specific ecodesign methods to support decision making on which products to develop? (For example: EQFD, MET matrix; E-FMEA, ecodesign checklist, or other.) Please elaborate.
11. Does the company use guides or specific environmental legislation to guide the development of new products? Please elaborate.
12. What are the main barriers or needs in the incorporation of environmental aspects in new product development process? Please elaborate.
13. In your opinion, how can environmental aspects influence decision making on which new products projects to develop?



Figure 1. An overview of the framework for integration between product portfolio management and ecodesign.

Table 1. Dimension: Guides, Methods and Tools.

Dimension	Guides, Methods, Tools	Applications	Examples	References
Group	Checklists, Scoring and Ranking	They have the potential to verify if environmental parameters are considered in PPM. They can be useful in the selection and prioritization of product projects by employing predefined evaluation criteria.	Ecodesign checklist method.	Rossi et al. (2016); Knight and Jenkins (2009); Vezzoli and Sciama (2006); Byggethand and Hochschorner (2006).
	Diagrams and Matrices	These allow estimation of the potential for improvement in the environmental performance of the projects of evaluated products. They can provide forecasts related to the product life cycle.	Ecodesign strategy wheel, materials energy & toxicity (MET) matrix.	Rossi et al. (2016); Knight and Jenkins (2009); Le Pochat et al. (2007); Byggeth and Hochschorner (2006).
	Sustainable Guides	Management models can assist decision making regarding environmentally sustainable product projects.	ISO 14062:2002, BS8887-1:2006.	Luttropp and Lagerstedt, (2006); Vezzoli and Sciama (2006); Brezet and Van Hemel (1997).

Table 2. Dimension: Organization.

Dimension	Organization	Applications	Examples	References
Group	Integration with Stakeholders	Receiving the opinions of different stakeholders concerning product portfolio decisions.	Workshops to sensitize and receive ideas, opinions, suggestions regarding environmental aspects of the different stakeholders of product projects.	Juntunen et al. (2016); Salem et al. (2016); Marcelino-Sádaba et al. (2015); Pigosso et al. (2013); Hoejmosé et al. (2012); Vezzoli et al. (2012).
	Multifunctional Team	A team with representatives from the different areas/departments, including environmental ones, incorporating information and suggestions received from the product planning stage.	Multifunctional teams involved in the new product development with a representative of the environmental area/function.	Bocken et al. (2014); Jabbour et al. (2015).
	Environmental Manager or Specialist in the Development Team	Provides management information, translating technical environmental possibilities to other functions involved in the new product development.	Leader with technical knowledge in the environmental area and also managerial.	Prendeville et al. (2014); Petala et al. (2010); Borchardt (2010); Johansson (2002).

Table 3. Dimension: Strategy.

Dimension	Strategy	Applications	Examples	References
Group	Strategic Planning	Incorporate environmental and product life cycle aspects in product decisions related to strategic planning.	The firm's strategic plan contains objectives and information related to the application of ecodesign methods and tools in the product portfolio.	Gouvinhas et al. (2016); Brones and Carvalho (2015); Byggeth and Hochschorner (2006); Simon et. al. (2000); Poole et. al. (1999).
	Support from Top Management	Support and encourage only the development of products that are aligned with environmentally sustainable design and development.	Top management defines policies that prioritize the development of environmentally sustainable products.	Borchardt (2010); Petala (2010).
	Portfolio Review	Evaluate and decide, at previously defined moments, the prioritization or cancelation of projects according to environmental impact criteria.	Use of Go/No Go environmental criteria at the time of phase evaluation during pre-development and decision making, concerning products to be developed, maintained, or discontinued.	Petala (2010); Brones and Carvalho (2015).

Table 4. Results of the framework analysis (Guides, Methods and Tools dimension).

Dimension	Guides, Methods and Tools	
Proof quotes	Company A	<p>- In relation to sustainable development guides, the philosophy of natural agriculture is our guide, providing what we consider about sustainability, and it is precisely in this philosophy that we base ourselves, being our guide in relation to what will or will not be done.</p> <p>- An environmental checklist template was created by the product development team that is completed and discussed during product portfolio meetings. Before the product project goes into development, it goes through the checklist and through method evaluations, scores and rankings, and after that the management of this process is done by the product development sector, with the PMO (project management office) practices, which establishes methodologies and supports with documents and tools.</p>
	Company B	<p>- The application of tools before starting the production process would be positive; it would be great, both guides and checklists. Today we can identify failures in the development of some projects that, if they had been better evaluated, could have been avoided.</p> <p>- The tools checklist, matrix and diagrams are applicable; I can undoubtedly see myself applying these tools. Just so you can see, I can align with the work of production planning and control with these tools, the applicability is total.</p>
Relations with literature	Agreement that the use of traditional ecodesign tools may be useful to PPM.	
Differentiation from the literature	<p>It uses specific guides already developed for specific industrial sectors - in this case for the biodiversity sector. (company A)</p> <p>Application of ecodesign methods and tools in PPM can be enhanced through specialized organizational structure, in this case the Project Management Office - PMO. (company A)</p> <p>It does not adopt traditional ecodesign methods and tools that could be used in PPM, such as: EQFD, E-FMEA or MET <i>matrix</i>.</p> <p>They do not adopt guides recognized as ISO 14062: 2002. (both companies) However, they adopt procedures already established by the sector, such as the philosophy of natural agriculture. (company A).</p>	

Table 5. Results of the framework analysis (Organization dimension).

Dimension	Organization	
Proof quotes	Company A	<p><i>In the organizational point of view there is an environmental work with a focused work team; there are indicators of environmental and technical issues in partnership with EMBRAPA (Brazilian agricultural research corporation). There is in our case, not necessarily the manager, but a person who has the expertise to monitor the projects.</i></p> <p><i>There is also a multidisciplinary structure, as it has departments with professionals in its areas, including those with several areas of knowledge participating in the projects.</i></p> <p><i>Integration with stakeholders happens internally and externally to satisfy the consumer. We collect data and information on social networks and with our suppliers.</i></p>
	Company B	<p><i>Without the support of top management, a simple environmental initiative can find implementation barriers, since the function can be focused on the result of the operation and deprioritize the environmental aspect.</i></p> <p><i>Perhaps in some situations in smaller companies the presence of a consultant with specific knowledge may be relevant. This would be useful if it was not possible to have the full dedication of this employee due to the size and profile of the company.</i></p>
Relations with literature	Both	Adoption of multifunctional teams; presence of environmental specialist in product development teams, integration with stakeholders; top management support for the development of environmentally sustainable products.
Differentiation from the literature	Company A	Use of social networks to collect information on the development of environmentally sustainable products; support of research-oriented institutions (in this case, EMBRAPA).
	Company B	External ecodesign specialist in product development teams.

Table 6. Results of the framework analysis (Strategy Dimension).

Dimension		Strategy
Proof quotes	Company A	<i>We hold portfolio meetings, both updates and progress of the projects, as well as validations and discussion of possible barriers identified. For example, we were in the final stages of planning a product when it was realized that the issue of not using hormones would be a technological difficulty, so the process was stopped because it ran away from our principles.</i>
	Company B	<i>The company's strategy is to operate in the market with environmentally sustainable products. To this end, top management directs product development activities from the selection of raw material from reforestation.</i> <i>Without the support of top management, a simple environmental initiative can find implementation barriers, because the operator may be focused on the output of the production and not prioritize the environmental aspect.</i>
Relations with literature	Company A	Use of stage-gate for product portfolio review.
	Both	Top management support in the strategy of acting in the market for environmentally sustainable products.
Differentiation from the literature	Both	Nothing found.